Evaluation of Design Features in Interactive 3D Tracts-of-interest Selection Tools in DTI

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ABSTRACT

We present a set of findings from our user evaluation of state-of-the-art TOI selection techniques. Tractography is a standard approach for visualizing the brain's white matter structure that is based on diffusion tensor imaging (DTI), and brain scientists need very efficient tools to select tracts-of-interest (TOI) for their research. We performed two evaluations aimed at better understanding of the tools: a subjective study of three standard TOI selection tools looking at the utility, usability and user satisfaction with the design features, and a user performance evaluation to measure the time performance and subjective reliability of two of the three standard TOI selection tools.

Index Terms: J.3 [LIFE AND MEDICAL SCIENCES]: Medical information systems—

1 INTRODUCTION

The most popular approach to extract the underlying fiber structure from DTI data is tractography: reconstructing trajectories from DTI using streamtubes/streamlines. Selecting TOI for segmentation is the most frequent task in most clinical research studies using DTI tractography, such as [5]. Several TOI selection techniques have been proposed to allow expert users to obtain clustering interactively [3, 2, 4, 7]. Different TOI selection methods give users different levels of flexibility and efficiency in clustering the fiber tracts. It is unclear which TOI selection method and combination of interaction techniques gives the expert user the best tools for the clustering task, and to the best of our knowledge, no studies have compared TOI selection techniques. We present the results from our user study evaluating the design features in three different TOI selection tools. We hope that this study will improve the design of TOI selection tools and thus help brain scientists in brain diagnoses.

2 METHODS FOR EVALUATING TOI SELECTION TOOLS

We performed two user evaluations to gain insights into the nature of TOI selection tools for DTI. Four domain experts took part in both experiments. All TOI selection tools evaluated in the experiments ran on the same desktop hardware setup, and the dataset used was DTI scans from a normal subject.

2.1 TOI Selection Tools Studied

A number of tools have been developed for interactively selecting TOI for fiber tracts; we look here at the TOI selection technique component of each interface. We evaluate and discuss three standard TOI selection tools: Brainapp, an interactive TOI selection application adapted from [3], CINCH [2], and MedINRIA [7]. Other tools such as DTI Studio [1] were not included in the study because their TOI selection techniques do not differ significantly from the three above.

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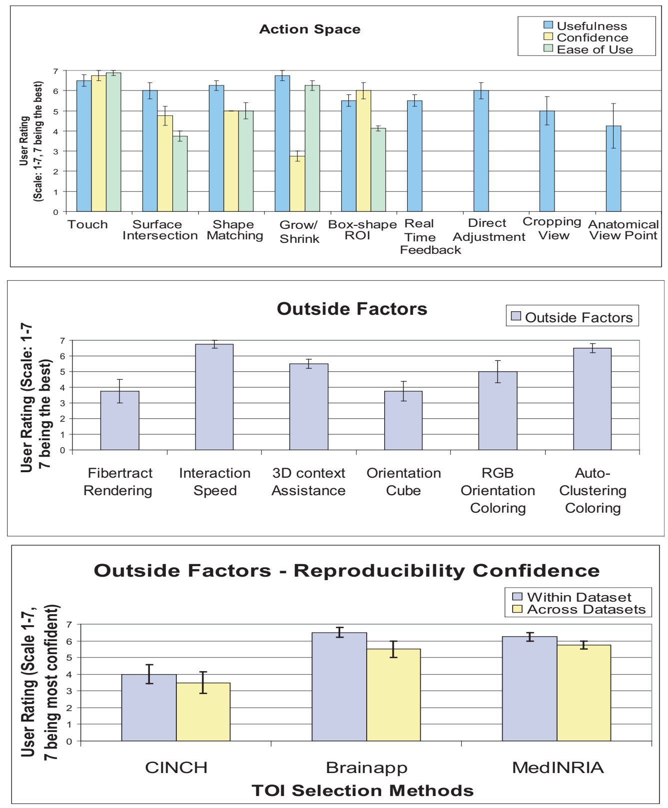

Figure 1: Subjective user evaluation results. Top: action space, bottom two: outside factors

2.2 Task

- **Experiment 1: Subjective User Evaluation**

Our goal here was a qualitative evaluation of the utility, usability and user satisfaction with different features of three TOI selection tools: Brainapp, CINCH, and MedINRIA. Participants were first trained on the techniques provided by each tool until they were reasonably proficient. They were then asked to select the corpus callosum, one of the most important white matter structures in the brain. After the experiment, participants were asked to provide a subjective rating on the utility, usability and user satisfaction with its features; the ratings ranged from 1 to 7, 7 being the best. Our questionnaire considered the action space (features affecting how users interact with the model) and outside factors (features that assist in the selection process such as visual enhancement).

- **Experiment 2: User Performance Evaluation**

Our goal here was to obtain performance data on TOI selection techniques, using controlled tasks in a simplified environment. We compared user performance in selecting four different fiber bundles defined in [8] using two standard tools: Brainapp and CINCH. (We omitted MedINRIA because its TOI selection interaction overlaps

Brainapp and CINCH.) The four white matter structures – corpus callosum (CC), cingulum bundle, superior longitudinal fasciculus (SLF), and uncinate fasciculus (UF) – were chosen to cover the complexity and variation in fiber bundles. The time participants took to make satisfactory selection of each assigned structure using each tool was recorded, and they were then asked to provide a confidence score for their final result on the basis of two criteria: correctness and completeness [6].

2.3 Results and Discussion

2.3.1 Subjective User Evaluation Results

Figure 1 shows the result of our subjective user evaluation. Below we highlight some of the most interesting findings.

Action Space:

- **The *touch* tool was rated highest in all three rating categories**

Our analysis suggests two main reasons for its high performance. First, much of the selection process involves refining the selection results by removing outliers on the basis of anatomy; second, the marking operation is also intuitively easy to understand, so that users gained confidence in using the tool. However, this has the disadvantage that some of those outliers might be the result of disease. Note that the *box-shape VOI* method in Brainapp usually avoids this problem since ROIs are placed strictly on the basis of the standard starting and ending positions of the structure in the brain.

- **The *shape match* and *grow/shrink* had a high average score of 6 in terms of usefulness. However, the confidence score was rather low; in particular, *grow/shrink* had an average rating of only 2.7 out of 7.**

Outside Factors:

- **The scores for the usefulness of anatomical viewpoint control had the biggest variance range, 2-7.**

This suggests that the usefulness of this feature depends strongly on user preference. Providing brain scientists with anatomical viewpoint could be an essential component of TOI selection tools targeting those users who experience relatively higher difficulty in model navigation.

- **Users had high confidence in the reproducibility of their TOI selection result in Brainapp and MedINRIA, but much lower confidence in the reproducibility in CINCH.**

The box-shaped ROI method in Brainapp and MedINRIA has the advantage of systematically placing ROIs based on standard selection protocols [8]. Selection in CINCH depends strongly on drawing arbitrary marks. It would be hard for a brain scientist to come up with a recipe to make their TOI selection reproducible.

2.3.2 User Performance Evaluation Results and Discussion

Figure 2 shows the time and confidence scores in picking out the four assigned white matter structures. CINCH outperformed Brainapp in all three structures except the UF. This is an unexpected result, since UF is a curving arc-shaped structure in the frontal lobe and we would expect the box-shaped regions to perform poorly in capturing this structure. We conjecture that this result occurred because: (1) The UF is at the outermost part of the frontal lobe of the brain, and a box can be placed at this location without too much occlusion, and (2) Most of the participants chose to use the *shape match* operation in CINCH due to the special curving shape of the structure. Unfortunately, the algorithm performed very poorly in locating this shape, frustrating the users and delaying the whole selection process.

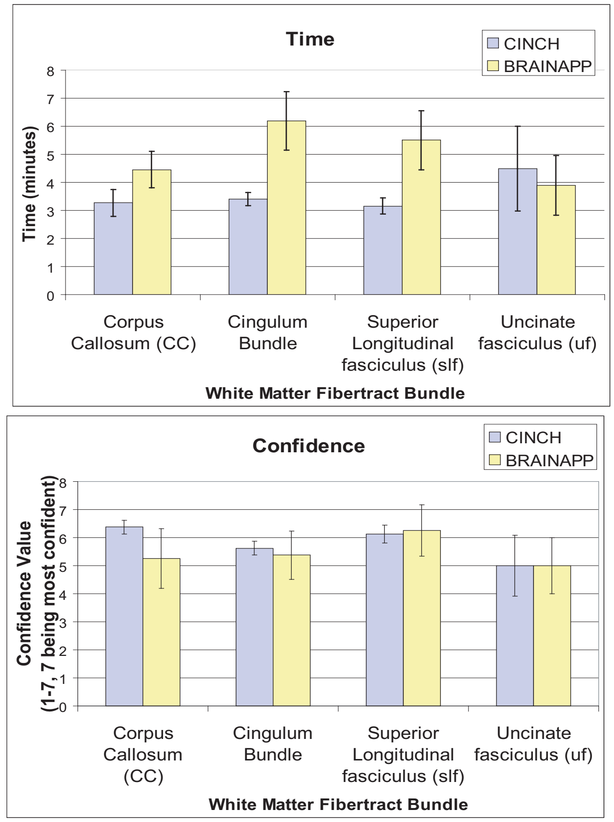

Figure 2: User performance evaluation results: time and confidence

3 Conclusion

Evaluating and comparing the relative merits of different TOI selection methods for fiber tract selection leads toward a formal understanding of the state-of-the-art in TOI selection tools. Giving users relatively simple fixing/erasing mechanisms such as the *touch* mark in CINCH is very useful. The reproducibility of the selection methods should be carefully considered in the implementation so that users can reliably reproduce scientific analysis. Semi-automatic selection algorithms based on embedded data have high potential to provide users with more efficient tools.

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